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Application of Computer Simulation Technology [CST] in Buildings' Performance-Based Fire Protection Design

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Abstract

This paper intends to discuss studies made in computer simulation technology [CST]'s application in buildings' performance-based fire protection design. On the basis of definition of the safety objective and performance evaluation for fire protection purposes and in combination of particular project details, internationally accepted software like FDS (a fire simulation software) and Building EXODUS (a personal evacuation simulation software) have been herein selected to simulate fire smoke spread and personal evacuation. Besides, expectations are made as to our development in fire computer simulation technology.

Keywords:Computer Simulation Technology [CST]; Performance-Based Fire Protection Design [PB-FPD]; FDS; Building EXODUS.

1. Introduction

With the rapid development of economy, our currently available fire protection codes fail to cover the increasing "loftiness, bigness, newness, grotesqueness, and uniqueness" in building construction and performance-based fire protection design (PB-FPD) has gradually evolved into a significant method or a technical tool to study and resolve such conditions in building fire safety. PB-FPD is a new method established upon fire science and fire engineering for building fire protection design. By availing principles and methods in fire protection safety engineering and in accordance with particular conditions in a building's structure, functional purposes and its internal flammables, PB-FPD is used in quantitative predication and evaluation of fire risks in a building, in order to obtain an optimum fire design plan and thereby provide the most reasonable fire protection for the building. In the solution of complicated building fire protection design, PB-FPD may remedy deficiencies of traditional formula fire design.

In recent decades, computer simulation technology [CST] is advantageous in safety, efficiency, and cost and has been increasingly used in fire study and has become a significant tool for quantitative analysis of a building's fire development features. Simultaneously CST application has promoted the

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evolution of our building fire protection code from a traditional formula code to a code for performance-based fire protection design.

2. Objectives and Performance-Evaluating Basis for Fire Protection Safety

Safety objectives in PB-FPD may be divided into life safety associated ones and other safety associated ones. The subdivision of such basic objectives may result in underlying particular objectives:

- satisfying personal life safety (as the chief objective) and ensuring safe personal evacuation to outdoors upon fire occurrence;
- preventing fire spread, reducing property losses and protecting environments; and
- guaranteeing firemen's fire-fighting actions, i.e., furnish a fire fighting vehicle passage, a fire protection elevator, windows for fire fighting rescue, and indoor and outdoor hydrants or the like to ensure firemen's smooth and timely entry into the scene of a fire.

As far as personal life safety is concerned, the design objective is defined as ASET>RSET, which means that the available safe evacuation time (ASET) is longer than the required safe evacuation time (RSET). This paper, taking a shopping mall as the example, a) uses the fire simulation software FDS, selects several typical fire scenes for smoke spread simulation, and makes calculations to obtain ASET; b) use the personal evacuation simulation software Building EXODUS to make a simulative calculation with regard to personal evacuation, i.e., firstly make an analysis of personal evacuation conditions in accordance with the assumed evacuation scene and then calculate accordingly to obtain RSET; and c) use personal life safety judgment bases and compare smoke speak conditions with personal evacuation simulation results to make a quantitative judgment as to personal evacuation safety.

Among them, ASET selection is made mostly on the basis of the fluctuation of the smoke layer's temperature, visibility limit, CO volume, etc. with the development of a fire in space and in time. The judgment bases thereof are defined as follows:

If the smoke layer height from the ground surface is less than 2m, then

- the average temperature of the smoke layer shall not be higher than 60℃;
- the visibility limit shall not be less than 10m; and
- the CO volume shall not exceed 0.05%.

3. FDS Fire Smoke Spread Simulation

3.1. Brief of FDS Software

FDS, a version of field model software specific for fire smoke spread simulation that is capable of simulating the smoke speed, the smoke temperature, and the smoke flow conditions as concerned, is developed from a CFD analysis program by Building and Fire Research Laboratory (BFRL) affiliated to National Institute of Standard and Technology (NIST). The software adopts a numerical method to solve the N-S equation associated with a flow of a lower Mach number as driven by fire buoyancy, especially on calculation of mass and heat transfer of a fire smoke.

The fire simulation software FDS consists of FDS and Smokeview, among which FDS functions as the main body of this software mostly for modeling and calculation of a fire scene; Smokeview acts as a visualized program for FDS calculation and is capable of dynamic data processing and static data displaying and these data is able to be displayed in 2 or 3 dimensions.

3.2. Simulation Parameter Setup

The FDS model established for the simulation object of this project is shown in Fig. 1. Upon such modeling, an overall consideration is made with respect to grid precision and calculation capability, etc. and the uneven grid generation method has been adopted, as the result, the grid size within the fire source adjoining area is 0.5m×0.5m×0.5m and the grid size within other areas is 1.0m×1.0m×1.0m.

Following assumptions are taken for simulative calculation of a smoke flow by availing FDS:

- Environmental Conditions: indoor and outdoor temperature, 24℃; pressure, 1 standard atm; without consideration of the wind speed, i.e., wind speed=0m/s;
- Opening Conditions: during fire simulation, with the exception of doors closed for fire protection, other doors shall remain open under normal usage;
- Fuel Type: upon simulative calculation, flammable selection has a material impact upon both smoke composition and smoke sediment height. Considering the complicatedness of flammables within a shopping mall, including but limited to office articles, clothing, and household electrical appliance, it is difficult to make a simulative calculation with respect to all flammables within the shopping mall. For a simplified calculation thereof, it is assumed that the flammable material is polyurethane with a rated smoke generation of 0.05g/g; and
- Matter Surface: insulating and inert.

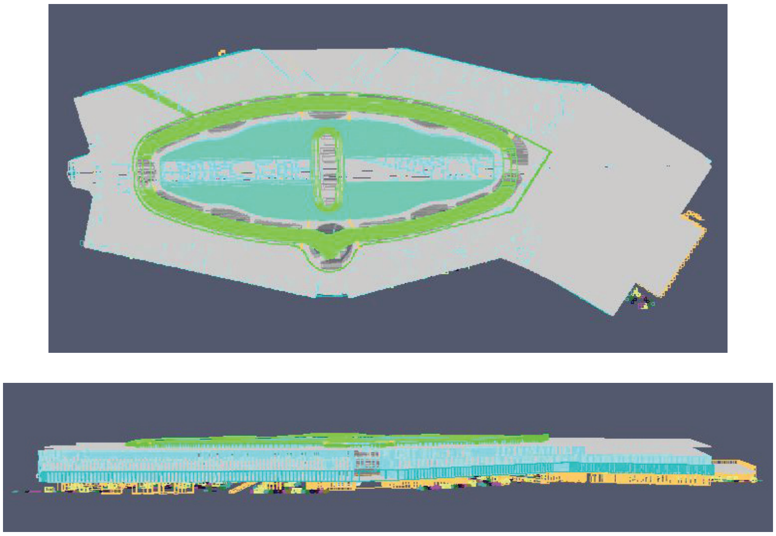

Fig. 1 A Building's FDS Model

3.3. Simulating Calculation Results

By taking a contemplated fire scene as the example, the smoke spread simulation results are shown in Fig. 2 and Fig. 3.

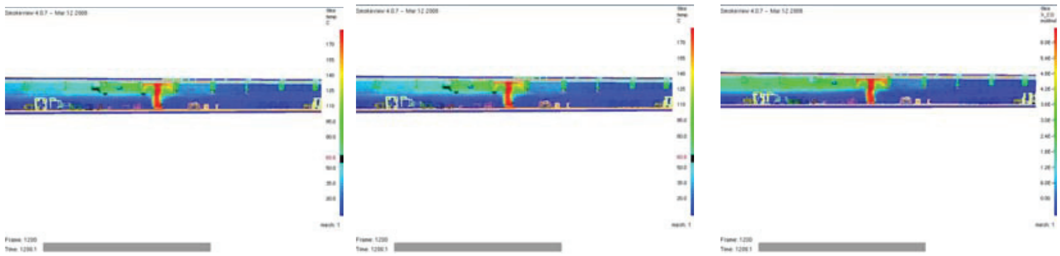

Fig. 2 Elevation Simulating Results (Temperature, CO Concentration, and Visibility)

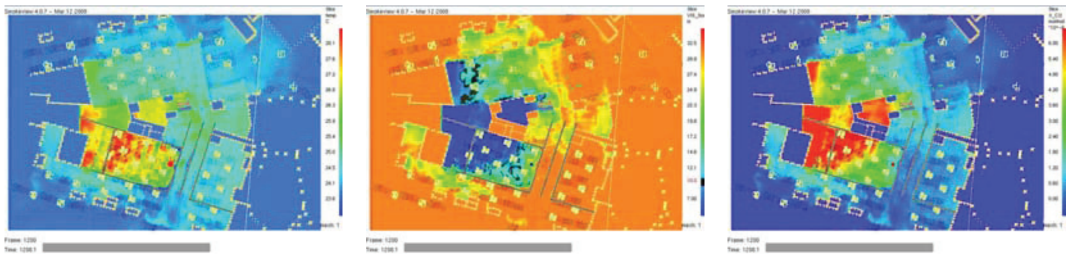

Fig. 3 Horizontal Plane Simulation Results (Temperature, CO Concentration, and Visibility)

4. Personal Evacuation Simulation with the aid of Building EXODUS

4.1. Brief of Building EXODUS Software

Building Exodus, one of computer simulation software associated with personal evacuation which has found rather popular use in simulative analysis of a personal evacuation process from within a building like a supermarket, a hospital, a railway station, and an airport. It pertains to a personal evacuation process simulating software with fine grids, containing 5 models thereunder: Occupant Model, Movement Model, Behavior Model, Toxicity Model, and Hazzard Model. In comparison with other personal evacuation process simulating software, Building Exodus has given due consideration to the interaction between evacuated persons, between evacuated persons and the building, and between evacuated persons and evacuation environments (such as a fire disaster). Therefore, Building Exodus may bona fide stimulate several attributes and behaviors of evacuated persons and the evacuation scene, trace many details occurred in an evacuation process, and give predicated results thereupon. Building Exodus contains a set of very strong result analysis tools, which enables an analysis process rather efficient and the analysis results rather clear and understandable.

4.2. Assumed Conditions for Simulation

Underlying assumptions are made for personal evacuation simulation with the aid of Building Exodus:

- evacuated persons have the same features and are available with enough body conditions to evacuate themselves to a safe locus;

- by referring to the statistic results concerning the number of persons to be evacuated from within a building, the number of persons to be evacuated at every scene from within the building is determined, appropriate personal evacuation arrangement by fire protection zoning is established, and a constant personal density in the same fire protection zone is guaranteed;
- within each building, every staircase is assumed as a smoke preventing type and every ante room as the a smoke preventing type too;
- each and all evacuated persons may start evacuation from the beginning and will not withdraw to chose any other evacuation route during evacuation;
- the personal stepping speed is automatically adjustable from 0.8 to 1.7 (m/s) according to the personal density within the current area; and
- with the exception of any fire incidence nearby, each and every evacuation passage and safe exit is ready for personal evacuation use. In each evacuation scene, flow rate control at each safe exit may guarantee the availability of maximum safe exit performance, basically ensuring simultaneous personal evacuation at each safe exit.

4.3. Simulation Results

By taking an example of the evacuation scene corresponding to the above-mentioned fire scene, the personal evacuation simulation results are shown in Fig. 4.

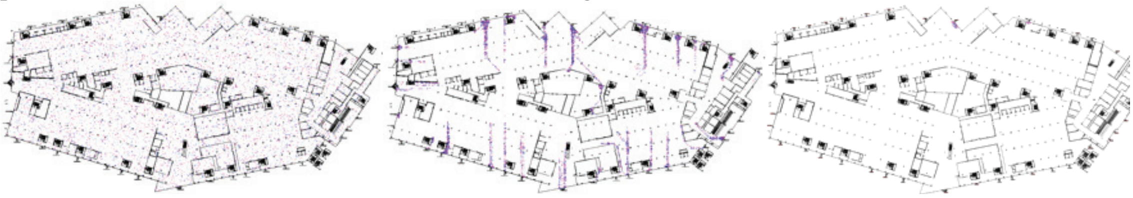

Fig. 4 Personal Evacuation Simulating Results

5. Safety Analysis as to Personal Evacuation

In according with ASET obtained through smoke spread simulation at the fire scene with the aid of the fire simulation software FDS and RSET obtained through personal evacuation simulation at each evacuation scene with the aid of the personal evacuation simulation software Building Exodus, comparison therebetween is made hereunder to determine the personal evacuation safety. The analysis results with respect to personal evacuation safety are shown in Table 1. The comparative results obtained through the personal evacuation safety analysis reveal that safe personal evacuation can be guaranteed at each and all contemplated fire scenes.

6. Conclusions and Expectations

With its advantages in science, safety and economy, performance-based fire protection design for buildings has gradually evolved itself into the development tendency in solving complicated fire protection design in a building. In addition, application of computer simulation technology in simulating a fire smoke spread process or personal evacuation constitutes a rather significant step in the overall performance-based fire protection design for a building. Through numerical simulation of a contemplated fire scene, a dynamic and quantitative analysis can be made as to the impact of a fire development process upon the selected serviceability conditions and thereupon the reliability and economy of a design plan concerned can be predicated and evaluated too. Thereby, upon project risk evaluation, data as the quantitative judgment basis for fire protection-associated decision making are available and further on, corresponding suggestions for modification purposes can be proposed to reduce investment input in fire protection and to enhance economic and social benefits of a building.

Table 1 Analysis Results as to Personal Evacuation Safety

Fire Scene	Available Safe Evacuation Time ASET(s)	Required Safe Evacuation Time RSET (s)	Safe Allowance = ASET-RSET (s)	Conclusions
A	737	613.5	123.5	Safe
B	>1200	613.5	>586.5	Safe
C	>1200	442.5	>757.5	Safe
D	>1200	520.5	>679.5	Safe
E	>1200	547.5	>652.5	Safe
F	>1200	517.5	>682.5	Safe

Our study in fire computer simulation technology has a rather late start and now remains in a groping phase. Currently only a few researchers are dealing with evaluation model researches and with self-owned development of simulation software, so a rather large difference does exist in comparison with the foreign technological development level. Therefore, in combination of the foreign experiences in fire computer simulation technology development and the domestic research status, we need to extensively initiate researches upon fire simulation software availability, to accelerate foreign software's localization, to make a successful self development of fire simulation software suitable to our situation, and to speed up the promotion of our fire computer simulation technology development.

Acknowledgement

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References

[1]Huo-Ran, Yuan-Hongyong. *Performance-Based Design and Analysis for Building's Fire Protection*. Hefei City: Anhui Provincial Sci-Tech Publishing House, 2003.

[2]Fan-Weicheng. *Fire Science Introduction*. Wuhan City: Hubei Provincial Sci-Tech Publishing House, 1987.

[3]*National Fire Protection Association* . NFPA 101 Life Safety Code, 2006 Edition.

[4]Mei-Xiujuan. *Performance-Based Design Method for Building's Fire Protection and Its Applications* . Fire Protection Technology and Relevant Product Info, 2004(1), p.8-10.